Maritime Industrial Waste Project

Reduction of Toxicant Pollution from the Maritime Industry in Puget Sound

Municipality of Metropolitan Seattle
Water Pollution Control Department
Industrial Waste Section
130 Nickerson Street, Suite 200
Seattle, WA 98109-1658
(206) 689-3000

March 1992

Acknowledgments

We would like to thank the following for their support and involvement in the Maritime Industrial Waste Project: U.S. Environmental Protection Agency, Region 10; Washington State Department of Ecology, Northwest Regional Office; City of Seattle, Department of Construction and Land Use; Metro Environmental Laboratory; Lake Union Association; Northwest Marine Trade Association; Seattle Marine Business Coalition; American Waterways Operators; and the maritime businesses and equipment suppliers who participated in the project.

This project was funded primarily by a grant provided to Metro by EPA's National Estuary Program, grant number CE-000201-01-0.

Contents

Tables and Figures

1. Introduction

Project Overview

In 1991, about 250,000 recreational boats were registered in the 12 counties bordering Puget Sound. Additionally, more than 5,500 commercial vessels were also operating in state waters in 1991 according to Washington state property tax records. About 26,000 recreational and commercial vessels are moored permanently in Puget Sound.

These statistics demonstrate the scale of maritime activity occurring in Puget Sound. They also point to the important role the maritime industry plays in the area's economy. The 1988 *State of the Sound* report estimated that direct and indirect boating sales in 1986 accounted for more than $3 billion in revenue and provided about 17,300 jobs statewide.

Maritime businesses around Puget Sound provide maintenance and repair services for this large and growing number of vessels. Several of these services, including hull-washing and painting, have been recognized as sources of pollution for wastewater and contaminated stormwater discharges. To date, wastewater discharges from most repair facilities have not been regulated directly. This condition is about to change with the development of new NPDES wastewater permits for these facilities by the Washington State Department of Ecology (Ecology).

The managers and operators of maritime repair facilities will be faced with the task of learning the new regulations, upgrading their facilities and, where necessary, installing wastewater treatment systems to control pollutant discharges. The U.S. Environmental Protection Agency (EPA), Ecology and the Municipality of Metropolitan Seattle (Metro) recognized the need to develop information that would help these managers and operators meet the requirements.

Project Description and Goals

The purpose of the Maritime Industrial Waste Project was to help establish the means and methods for reducing toxic pollutant discharges from the maritime industry in the Puget Sound area. The project focused specifically on the activities occurring at boatyards and shipyards that repair and maintain marine vessels.

To achieve the goal of reducing pollutant discharges from these facilities, the project investigated, pilot-tested and recommended appropriate treatment technologies and operational changes that could reduce the flow and/or toxicity of polluted discharges to receiving waters. The project placed particular emphasis on examining wastewater generated from hull-washing operations. Antifoulant paint used on the hull bottoms of ships and boats has been known to be a source of toxic contamination to hull wash water and stormwater.

In addition, the project, sought to assist and inform the maritime industry by providing treatment system design criteria and waste disposal guidelines. The project reasoned that a well-informed industry would move more readily and cost-effectively toward regulatory compliance than an uninformed industry.

The Maritime Industrial Waste Project was developed by Metro and was funded primarily through a grant from EPA's National Estuary Grant Program. Metro's Industrial Waste Section staff coordinated and conducted the project study.

Project Objectives

The new NPDES permits being developed by Ecology will set standards for maritime industry discharges to receiving waters and, in some cases, municipal sewers. Through the Maritime Industrial Waste Project, Metro sought to help the maritime industry and Ecology by characterizing maritime wastewater and identifying technologies that would help the industry meet the standard.

Specific goals of the Maritime Industrial Waste Project were to:

- Design and test prototype collection and treatment systems for hull-washing wastewater to determine which methods could consistently meet state and local standards
- Develop waste disposal guidelines that could be implemented while upgrading existing facilities or constructing new facilities
- Develop a plan for implementing the waste disposal guidelines in existing state and local permitting and enforcement programs for the Puget Sound basin on a trial basis
- Work cooperatively with other agencies, municipalities, business organizations and the maritime industry
- Examine waste-reduction and waste-minimization options and incorporate appropriate options into the waste disposal guidelines.

The Maritime Industrial Waste Project was conducted in three phases over a one-year period beginning in November 1990. The phases and major work tasks were as follows:

Phase I: Project planning, problem assessment and technical review

- Visit and inspect sites
- Characterize wastewater
- Select and categorize maritime businesses
- Review wastewater treatment technologies
- Establish pilot system vendor contacts and testing arrangements

Phase II: Treatment guidelines development

- Set up pilot treatment systems
- Evaluate treatment systems
- Evaluate other pollution attenuation options
- Develop industry guidelines document
- Develop trial basinwide implementation plan

Phase III: Education and assistance

- Develop and present project results to the maritime industry
- Provide field technical assistance.

2. Problem Assessment

The Maritime Industry in Puget Sound

In the Seattle metropolitan area, there are nearly 300 maritime businesses, including marinas, boatyards, dry docks and salvage yards. The majority of these businesses are located on Elliott Bay, the Duwamish River, Lake Union and the Lake Union Ship Canal.

Many more maritime facilities are scattered around Puget Sound in other urban areas, such as Tacoma, Everett, Anacortes and Bellingham, and in more rural areas, such as Liberty Bay and Port Orchard. There are 35 shipyards and 126 boatyards in the 12 counties surrounding Puget Sound, according to the Bureau of the Census (County Business Patterns, 1988). In addition, 74 marinas have reported that they offer boat repair services. These services are expanding rapidly as the Puget Sound region undergoes a tremendous growth in population.

Several of the large maritime operations have implemented best management practices and obtained NPDES permits from Ecology. While these permits have resulted in reductions of previously discharged pollutants, many of the operations continue to discharge untreated pressure-washing wastewater and contaminated stormwater. Typically, these discharges are high in copper, lead and zinc. To date, boatyard wastewater discharges have remained relatively unregulated, probably because of the small size of these operations. These facilities have traditionally released hull-washing wastewater directly to the nearest receiving water.

Through its individual NPDES permits and the general permit for boatyards currently being developed, Ecology has established a policy of eliminating the discharge of untreated pressure-washing wastewater to receiving waters and a policy requiring establishment of best management practices (BMPs) at these facilities to prevent the contamination of stormwater discharged from these facilities.

Antifouling Bottom Paints

Vessels which spend a substantial amount of time in the water usually have their hull bottoms painted with antifouling paints. These paints use biocidal agents to discourage the growth of marine organisms, such as seaweed, barnacles and mussels. The paint discourages growth by slowly leaching and sometimes sloughing the toxic component to the surrounding water. The paint remains an effective deterrent to marine growth until the biocidal component diminishes over a period of one to five years.

Copper compounds serve as the active biocidal agent in the most widely used formulations of antifouling paint. Copper antifouling paints can contain cuprous oxide in quantities of up to 70 percent by weight.

Tributyltin (TBT) is the active biocidal agent in some bottom paints. TBT has been shown to be 100 to 1,000 times more toxic to marine organisms than copper compounds. TBT has also been shown to have a detrimental impact on shellfish populations, though the extent of its impact is now being debated. TBT is also much more toxic to the persons applying the paint than copper-based paints.For these reasons, EPA has restricted the use of Tributyltin to certain vessels and required certification of applicators. Current regulations state that tributyltin paints are prohibited from use on any vessel less than 25 meters (82 feet) in length, with exceptions to aluminum boats and the outboard motors or the lower drive unit of vessels less than 25 meters in length. Persons applying tributyltin paints must have a pesticide applicators license from the Washington Department of Agriculture and have passed either the Aquatic TBT exam or a General Aquatic Antifouling exam.

Maritime Business Survey

To assess current industry awareness of pollution control regulations and the status of maritime operations, the Maritime Industrial Waste Project developed a survey (Appendix A). The survey, which included an invitation for businesses to participate in the pilot phase of the project, was sent to 239 maritime businesses in the Puget Sound Area.

The mailing list of the businesses was assembled from Seattle, Everett, Tacoma and south and north Puget Sound yellow pages and phone directories and from a membership mailing list supplied by the Seattle-based trade organization, Northwest Marine Trade Association.

The focus of the Survey was to gather information about hull-washing activities, which produce wastewater flows. Results of the survey are summarized in Table 2-1.

Categories of Repair Facilities

To distinguish boats from ships, Ecology has adopted the definition used by the U.S. Coast Guard: a boat is generally less than 65 feet in length, and a ship is generally more than 65 feet in length. By this definition, maritime facilities can be defined in the following way:

Shipyards

Facilities predominantly building or repairing commercial vessels more than 65 feet in length.

Boatyards

Facilities building and/or repairing vessels less than 65 feet in length. These facilities range in size from shops working on one to two boats at a time to large do-it-yourself yards with dozens of boats being worked on at a time.

Marinas/boatyards

Facilities offering boat moorage but also having a haul-out and either contracting repairs or allowing do-it-yourself repairs.

Marinas/moorages

Facilities only mooring boats and using no up-land yard space to conduct repairs.

Maritime businesses not directly engaged in waterside vessel-repair activities were not a focus of this study. Examples of these types of businesses are those involved in boat sales, marine engine repair and general manufacturing. These facilities may or may not need to have permits for discharging stormwater or industrial wastewater to the sanitary sewers, storm drains or receiving waters.

Identification of Repair Facilities for NPDES Permits

Ecology and maritime businesses have suggested several ways for identifying repair facilities that will be regulated for wastewater discharges under NPDES and/or sewer permits. One identification method is the existence of a vessel haul-out device, such as a dry dock or a crane. Another identification method is the availability of repair activities that might result in waste discharges.

Haul-outs used at boatyards and shipyards include:

- Dry docks
- Graving docks
- Marine railways
- Cranes

Table 2-1: Survey Results

Survey Statistics	
Total letters sent	239
Returned without forwarding	10
Total contacts	229
Surveys returned (22 percent of total contacts)	51

Categories of Facilities Responding to Survey	
BOATYARDS	
Boatyards	16
Marina/boatyard	9
BOATYARDS TOTAL	**25**
SHIPYARDS	
Shipyards	8
SHIPYARDS TOTAL	**8**
OTHER	
Marina/moorage	5
Marine service shops	11
Other	2
OTHER TOTAL	**18**

Wastewater Discharge Status	BOATYARDS			SHIPYARDS		
	Yes	No	Applied	Yes	No	Applied
NPDES permit	0	21	4	4	0	4
Sewer permit	1	21	3	3	4	1
Sewer available	17	8	8	0		
Wastewater treatment	2	23		1	7	
Stormwater collection	11	14		5	3	

Types of Operations	BOATYARDS	SHIPYARDS
Repair and maintenance	25	8
Vessel construction	3	3
Pressure-washing	20	8
Hydroblasting	1	3
Dry grit-blasting	1	8

Location of Operations	BOATYARDS	SHIPYARDS
Over land	17	7
Over water	14	8
On land and over water	7	7

Haul-outs	BOATYARDS		SHIPYARDS	
	Number of Yards Using	Number of Haul-outs Total	Number of Yards Using	Number of Haul-outs Total
Dry docks	8	3	6	16
Cranes	8	9	1	1
Travel lift	10	11	0	0
Marine railway	5	7	4	5
Graving dock	0	0	1	1
Launch ramp	3	3	0	0

- Stationary hoists and travel lifts
- Ramps.

Dry docks, graving docks and marine railways are the haul-outs most often observed at shipyards. Dry docks and marine railways may also be used in boatyards.

Boatyard and shipyard activities that might be associated with waste generation are:

- Hull-washing, by low pressure, high pressure or hand-washing
- Paint-stripping and surface preparation, using hydroblasting, sanding, scraping, grit-blasting or other means
- Bottom-hull and top-side painting
- Vessel structural repairs
- Bilge and ballast tank-pumping and/or tank-cleaning
- Prop, shaft and rudder replacement or repair
- Marine sanitation device (MSD) repair or replacement

When antifouling paints are present, pressure-washing hull bottoms produces wastewater contaminated with heavy metals. Although the terms hydroblasting and pressure-washing are sometimes used interchangeably, there is a difference. Pressure-washing usually refers to washing under pressures of 1,500 to 5,000 psi to remove organic growth and peeling paint. Hydroblasting uses water pressure of more than 30,000 psi to strip paint off steel hulls down to bare metal. A grit sometimes is used in hydroblasting to enhance the stripping process. To avoid confusion, all hull-washing activities in this report will be referred to as pressure-washing.

Sanding, scraping and dry grit-blasting hull bottoms produces dry residue that is contaminated with heavy metals found in antifouling paints. As dry particulates, the residues can contaminate adjacent land and waters.

When the residues settle on exposed yard surfaces, they can become a major source of contamination to stormwater and, in turn, nearby waters.

Painting operations generate air emissions of particulate and volatile organic compounds and hazardous wastes such as used paints and solvents. If not contained, particulates generated from painting operations can also contaminate yard surfaces and contribute to stormwater contamination.

Depending on materials used, vessel structural repair and repairs to the prop, shaft and rudder can generate air emissions and solid wastes.

Bilge-pumping and bilge-cleaning can generate oily or oil emulsified wastewater with contaminants that may have entered the bilge. If fuel was spilled in the bilge or solvents were used to clean the bilge, oil in the bilge water may become emulsified.

Marine sanitation device and sewage holding-tank repair or replacement can generate sewage wastewater.

Description of Repair Facilities

Boatyards and marinas with repair operations may vary significantly in size and volume of business. A boatyard with one haul-out, such as a crane or travel lift, is an example of a small repair facility. It may employ several people and have an upland yard area capable of handling one to several vessels. An office and workshop may be the only covered buildings on the property.

Typical Boatyard Sites

A boatyard usually uses a crane, travel lift or marine railway for its haul-out. The yard ordinarily has a dock or pier area where boats can be moored temporarily for repairs in the water or for haul-out. Roofed docks are not common, and enclosed buildings over water are rare. In urban areas where shoreline space is at a premium, such as Lake Union in Seattle, some boatyards use a concrete-surfaced work pad set on pilings over the water. Boats can be hauled onto the pad by a crane. There may be no upland repair area at these boatyards.

Boatyards with upland areas, known as the "yard", provide several main functions, including hull-washing, painting and temporary vessel storage while mechanical and structural repairs are being made. Boats are serviced or repaired while being supported by portable bracing structures, such as jack stands or cradles.

A partial survey and inspection of boatyards around Puget Sound revealed that boatyards in urban areas, such as Seattle, have a high percentage of paved or mostly paved yards and haul-out areas. The reverse is true for yards in rural areas and smaller towns around Puget Sound where a majority of yards and haul-out surfaces remain unpaved.

Boatyards usually repair or service recreational boats, such as sailboats and power boats. The hull surfaces of these boats are predominantly made of fiberglass or wood. Boatyards with larger capacity haul-outs, such as marine railways, can work on commercial boats less than 65 feet in length. Many of these boats are fishing boats with wood or fiberglass hulls.

Wastewater volume from pressure-washing varies depending on the size of the boatyard, the time of year and the extent to which pressure-washing is done. Based on the survey and site visits the Maritime Industiral Waste Project estimates that an average 100 boats are pressure-washed each year. A typical wash of a typical boat generates about 75 gallons of wastewater. A typical boatyard, therefore, generates about 7,500 gallons of wastewater per year. On a daily basis, a boatyard may not generate any wastewater or may generate as much as 750 to 1,000 gallons.

Typical Shipyard Sites

Typical shipyard sites were found to have large-capacity haul-outs, such as floating dry docks and marine railways. With the exception of a small number of large pleasure yachts, shipyards work on many types of commercial vessels predominantly made of steel. Larger wood-hulled fishing boats are also significant customers.

Over-water areas at shipyards were found to include one or several floating dry docks and the piers or docks to serve them. Because floating dry docks are predominantly used as haul-outs at shipyards, most repair and maintenance activities occur while the vessel is lifted out of the water on the dry dock. Ancillary shops, including machine shops, tool rooms, office and parking lots, are located mostly onshore. Shipyards with marine railways haul ships onto land for repairs.

Based on field data, the average volume of pressure-washing wastewater used on each ship is 1,625 gallons, calculated on the basis of a 65-foot vessel producing 25 gallons of wastewater per foot. Wastewater generation at shipyards averages about 120,000 gallons per year based on pressure-washing 75 ships per year. A shipyard may not generate any pressure-washing wastewater or may generate as much as 15,000 gallons of wastewater in a day. On large dry docks, rainwater can add several thousand gallons of wastewater to the daily volume.

Pollution Control Status

Boatyards

Survey results and inspections confirmed that a very low percentage of boatyards have permits for discharging wastewater to municipal sewage systems or receiving waters. To a large extent, those that have applied for permits have done so in response to a visit or complaint investigation by Ecology. Boatyards with high visibility in urban settings were probably more susceptible to complaints and follow up inspections.

Two out of 25 boatyards in the survey indicated they were treating pressure-washing wastewater. Each boatyard treated wastewater through retention and settling. During the Maritime Industrial Waste Project, several other boatyards implemented settling treatment as a preliminary step before discharging to the sewers. More advanced treatment, such as chemical flocculation and settling, was pilot-tested during the project. At least one boatyard has implemented this type of treatment.

Wastewater discharge from boatyards are regulated to a lesser degree than larger industries are. This level of regulation extends to air pollution controls, stormwater contamination controls and solid waste management. Many boatyards visited during the project have implemented some controls, primarily in response to suggestions from business associations and site visits from regulatory agencies. This approach, which has not always been effective and equitable, has produced a range of pollution control conditions at boatyards.

Most small boatyards are classified by Ecology as "small-quantity generators," producing less than 220 pounds of hazardous waste or 2.2 pounds of extremely hazardous waste per month or per batch. Some larger boatyards may generate enough hazardous waste, particularly from solvents and paints, to be classified as "regulated generators" generating between 220 pounds and 2,200 pounds of hazardous waste per month or per batch.

Shipyards

Because of their larger, more visible operations and higher quantities of wastewater discharges, shipyards have come under greater environmental scrutiny in recent years. The eight shipyards surveyed usually had an employee specializing in environmental affairs. These shipyards either held a NPDES permit or had applied for one.

NPDES permits issued to shipyards in the last 10 years have set contaminant limits for hull pressure-washing discharges that did not necessarily require specialized treatment. Limits on copper in hull-washing wastewater, for example, were set in the range of 1 to 10 parts per million. Compliance was technically achievable by employing several source-control measures, such as reducing the wash pressure and routinely cleaning dry dock decks. In some cases, rudimentary treatment was provided by capturing some of the wastewater solids in filter bags before releasing wastewater overboard. Because the new and renewed NPDES permits will be based on water quality standards with stricter limits, shipyards will have to collect wastewater and provide more effective treatment.

Shipyards have also been more regulated for air emissions, stormwater flows and waste solids management. As shown in the survey, grit-blasting used to strip paint and rust from hulls before painting is an activity widely performed at shipyards. The activity produces dust and grit contaminated with heavy metals. The dust produces air emissions of immediate concern, while the contaminated grit creates the potential for stormwater contamination.

Shipyards also generate substantially more hazardous waste than boatyards do. A high percentage of the hazardous waste results from painting operations.

Large shipyards are classified either as "regulated generators" or as "fully regulated generators," producing more than 2,200 pounds of hazardous waste or 2.2 pounds of extremely hazardous waste per month or per batch.

[redacted]

Table 2-2: Pressure-washing Wastewater – Boatyard Analytical Data Summary

Analytical Parameter	Units	Total Sample					Filtered Sample [1]				
		Number of Samples [2]	Number of Samples [3]	Minimum (ppm)	Maximum (ppm)	Average (ppm)	Number of Samples [2]	Number of Samples [3]	Minimum (ppm)	Maximum (ppm)	Average (ppm)
Conventionals											
pH		18	18	6.7	8.2	7.2					
Conductivity	(umhos/cm)	18	18	70	27,000	3,814					
Turbidity	(ntu)	18	18	23	1,700	469					
Suspended solids	mg/l	18	18	34	3,100	800					
Settleable solids	ml/l	6	6	7	24	12					
COD [4]	mg/l	13	13	31	1,300	387	7	7	18	110	40
Metals											
Cadmium	ppm	18	11	0.002	0.076	0.02	9	3	0.004	0.009	0.007
Chrome	ppm	18	17	0.007	2.7	0.23	9	1	0.08	0.08	0.08
Copper	ppm	18	18	2.5	190	55	9	9	0.6	14	2.9
Nickel	ppm	18	13	0.02	0.17	0.057	9	1	0.01	0.01	0.01
Lead	ppm	18	17	0.1	14	1.7	9	1	0.1	0.1	0.1
Zinc	ppm	18	18	0.62	22	6.0	9	9	0.08	3.2	1.0
Tin	ppm	18	14	0.06	1.4	0.49	9	2	0.05	0.1	0.07
Arsenic	ppm	18	4	0.07	0.1	0.08	9	0	0.05	0.05	0.05

[1] Using a 0.45-micron filter.
[2] Total number of samples analyzed.
[3] Number of samples where values were above detection limits.
[4] Chemical oxygen demand.

Characterization of Pressure-washing Wastewater

Tables 2-2 and 2-3 summarize wastewater characterization data for conventional and metal pollutants in hull-washing wastewater. Multiple samples were taken at 10 boatyard sites and 6 shipyard sites between December 1990 and June 1991. Complete wastewater characterization data is presented in Appendix B.

Whether generated by pressure-washing, hydroblasting or hand-washing, hull-washing wastewater has a turbid appearance from particles suspended in solution. Hull-washing operations produce the suspended particles by physically abrading the painted surface. If the paint on the hull being washed is blistered and peeling, the amount of solids removed during washing increases substantially. The small particles of paint removed by washing also become interspersed with larger particles of marine growth, such as fragmented seaweed and barnacles.

Table 2-3: Pressure-washing Wastewater – Shipyard Analytical Data Summary

Analytical Parameter	Units	Total Sample					Filtered Sample [1]				
		Number of Samples [2]	Number of Samples [3]	Minimum (ppm)	Maximum (ppm)	Average (ppm)	Number of Samples [2]	Number of Samples [3]	Minimum (ppm)	Maximum (ppm)	Average (ppm)
Conventionals											
pH		39	39	6.1	8.7	7.23					
Conductivity	(umhos/cm)	37	37	96	29,800	3,613					
Turbidity	(ntu)	37	37	3	840	176					
Suspended solids	mg/l	33	33	22	693	261					
Settleable solids	ml/l	16	7	0.7	50	11					
COD [4]	mg/l	18	18	140	740	302	12	12	20	200	60
Oil/grease	mg/l	5	4	9.9	31	20					
Metals											
Cadmium	ppm	40	33	0.002	0.05	0.01	17	4	0.003	0.006	0.004
Chrome	ppm	40	35	0.006	2.7	0.1	17	1	0.007	0.007	0.007
Copper	ppm	40	40	0.12	49	12.5	17	17	0.11	3.6	0.8
Nickel	ppm	40	32	0.01	0.42	0.05	17	1	0.01	0.01	0.01
Lead	ppm	40	28	0.03	1.7	0.34	17	2	0.04	0.1	0.07
Zinc	ppm	40	40	0.22	33	6.6	17	17	0.05	2.1	0.6
Tin	ppm	23	11	0.06	1.6	0.34	6	1	0.05	0.05	0.05
Arsenic	ppm	40	4	0.07	0.3	0.2	17	0	—	—	—

[1] Using a 0.45-micron filter.
[2] Total number of samples analyzed.
[3] Number of samples where values were above detection limits.
[4] Chemical oxygen demand.

Copper is the major contaminant of concern in hull-washing wastewater. The presence of copper is expected since the most common antifouling paint preparations contain cuprous oxide as the active biocidal component. In this project, the average total copper concentrations for boatyard and shipyard pressure-washing wastewater were 55 and 12.5 parts per million, respectively.

Antifouling paint also contains lead and zinc, though some of the zinc present in wastewater may also come from anticorrosive primer coatings and metallic zinc used for cathodic protection.

The project also analyzed wastewater samples for elemental tin as an indicator of tributyltin compounds. Tin concentrations ranged from 0.06 to 1.4 parts per million for boatyards and from 0.06 to 1.6 parts per million for shipyards. The average concentrations of tin for boatyards and shipyards was 0.34 and 0.49 parts per million, respectively.

Laboratory analysis of total and dissolved fractions (passing 0.45 micron filter) of field samples confirmed that the highest percentage of metal contamination in wastewater was contributed by suspended solids. Dissolved metal contamination was relatively low. Based on the average values for total and dissolved metals in boatyard wastewater, analysis showed that suspended solids accounted for 97 percent of the copper, 94 percent of the lead and 83 percent of the zinc. A similar analysis for shipyard wastewater indicated that suspended solids accounted for 94 percent of the copper, 80 percent of the lead and 91 percent of the zinc.

Chemical oxygen demand (COD) was used as a rough measure of the biodegradable organic content in the wastewater. The survey data showed the average values of COD in hull-washing wastewater to be of the same magnitude as COD in a dilute sewage wastewater. This COD concentration can produce low oxygen conditions and decay odors and gases in the wastewater that is not treated. This result was confirmed in the field. As with metals, COD is contributed mostly by wastewater suspended solids, comprising 80 percent of shipyard wastewater COD and 90 percent of boatyard wastewater COD.

Two particle-size/settling experiments were performed on boatyard and shipyard composite samples. The experiments related particle size, as a function of settling time, to the concentration of metals in wastewater. Figure 2-1 illustrates that particles less than 60 microns in diameter contribute 80 to 90 percent of the copper contamination in suspended solids. Particles less than 20 microns in diameter contribute about 50 percent of the copper. This finding is important since particles of this size settle out of solution slowly, making simple settling an ineffective means of treatment.

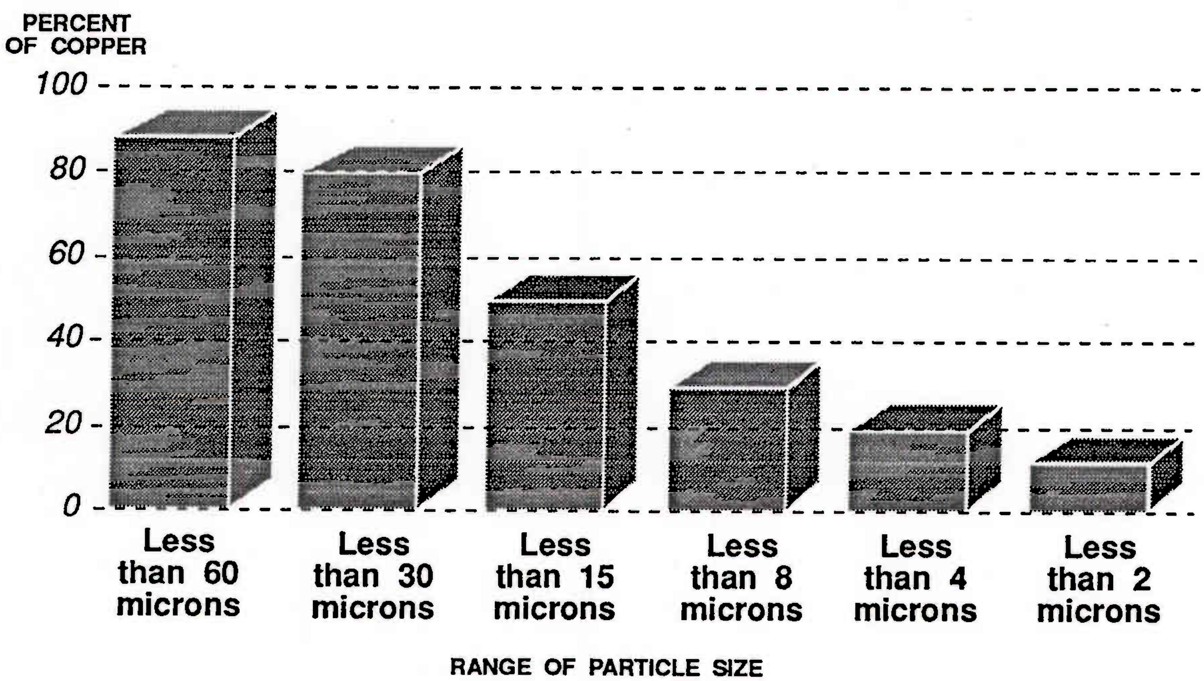


Figure 2-1: Percent of Copper Versus Particle Size – Boatyard Pressure-washing Wastewater Sample

Visible inspection for the presence of an oil sheen and analysis of several samples showed that oil and grease contamination was not a normal problem in wastewater samples. Oil and grease is a possible problem in pressure-washing wastewater if oily bilge water has been spilled during washing operations.

Organic contamination was not found to be a problem in five pressure-washing samples analyzed for volatile organic compounds and extractable organic compounds. Only a small number of organic compounds, such as phthalates and polynuclear aromatics (PAHs), were found at low concentration levels – between 10 and 100 parts per billion – in the samples tested. Organic contamination in the form of spilled fuels or solvents could become a problem in pressure-washing wastewater if they are spilled or leaked during washing operations.

Boatyard and Shipyard Comparison

Measurements of wastewater turbidity and concentrations of suspended solids, and the metals copper and lead were found to be about three to four times higher at boatyards than at shipyards. The field data determined that about eight times more water was used per length of vessel at shipyards than at boatyards – 25 gallons of water was used per foot of vessel at shipyards compared with 3 gallons per foot of vessel length at boatyards. This difference is probably due to several factors, including the greater draft of the larger vessels, the efficiency of washing a smaller vessel and the quantity of marine growth that needed to be removed from the hull. Average COD concentrations were similar for boatyard and shipyard wastewater, suggesting that significantly higher quantities of organic material had to be removed from ships than from boats.

The average zinc concentration was also found to be similar at boatyards and shipyards. The greater use of anticorrosive primer paints containing zinc on steel ships possibly accounts for this result.

Contaminants of Concern

Copper and lead were the pressure-washing wastewater contaminants found to exceed sanitary sewer limits consistently. Though lead was found to exceed limits less often than copper, the fact that high concentrations can occur means that lead should be regarded as a contaminant of concern. Oil and grease and possible organic contamination from solvents that have spilled into pressure-washing wastewater can be a problem if well-designed pollution prevention practices are not followed.

Tables 2-4 and 2-5 and Figures 2-2, 2-3 and 2-4 compare the average concentration of contaminants in pressure-washing wastewater to the limit concentrations established for discharges to sewers and receiving waters. The comparisons show that, in general, the average concentrations for copper, lead and zinc in pressure-washing wastewater are near or higher than sewer limit concentrations and from one to 2,000 times higher than NPDES receiving water limits, depending on the metal. The average copper concentration for boatyard wastewater, for example, is 55 parts per million. This amount is 23 times higher than the NPDES sewer limit and 1,800 times higher than the NPDES receiving water limit.

Discharge Routes for Pressure-washing Wastewater

There are several wastewater discharge routes for shipyards and boatyards. They include:

- Receiving waters (river, lake or ocean)
- Sanitary sewers (served by a municipal treatment plant)

[redacted]

Table 2-4: Boatyard Pressure-washing Wastewater Contaminants and Regulatory Limits

Analytical Parameter	Units	Untreated Sample (average) [1]	Untreated Sample (high)	Permit Limit Values			
				Sanitary Sewers (Metro)	Boatyard NPDES		
					Sanitary Sewers	Receiving Waters [6]	
						Marine	Fresh
pH	pH	7.2	6.7 - 8.2	5.5 - 12.0	[3]	[4]	[4]
Turbidity	ntu	469	1700	[3]	[3]	[4]	[4]
Suspended solids	mg/l	800	3100	[3]	[3]	[3]	[3]
Oil/grease	mg/l	[2]	[2]	100	[3]	[4]	[4]
Copper	mg/l	55	190	8.0	2.4	0.030	0.090
Lead	mg/l	1.7	14	4.0	1.2	1.40	0.650
Zinc	mg/l	6.0	22	10.0	3.3	0.950	0.340
Tin	mg/l	0.49	1.4	[5]	[5]	[5]	[5]
Arsenic	mg/l	0.08	0.1	4.0	3.6	0.690	3.60

[1] Values are based on analysis of 18 samples.
[2] Oil and grease not detected by visible inspections.
[3] No limit set or known for this parameter.
[4] No monitoring requirements, but limits will be based on water-quality criteria.
[5] Tin regulated by restrictions on the application of Tributyltin paints.
[6] Limit values based on a March 1992 draft of the Boatyard General NPDES Permit.

- Zero-discharge

  Recycling in a closed-loop system
  Evaporating the total waste stream
  Eliminating pressure-washing
- Removal by a waste disposal company.

The advantages and disadvantages of the discharge routes are presented in Table 2-6. The most advisable discharge route for all boatyards and shipyards was identified to be the sanitary sewer route. From a treatment perspective, this route is the most cost-effective and achievable route overall.

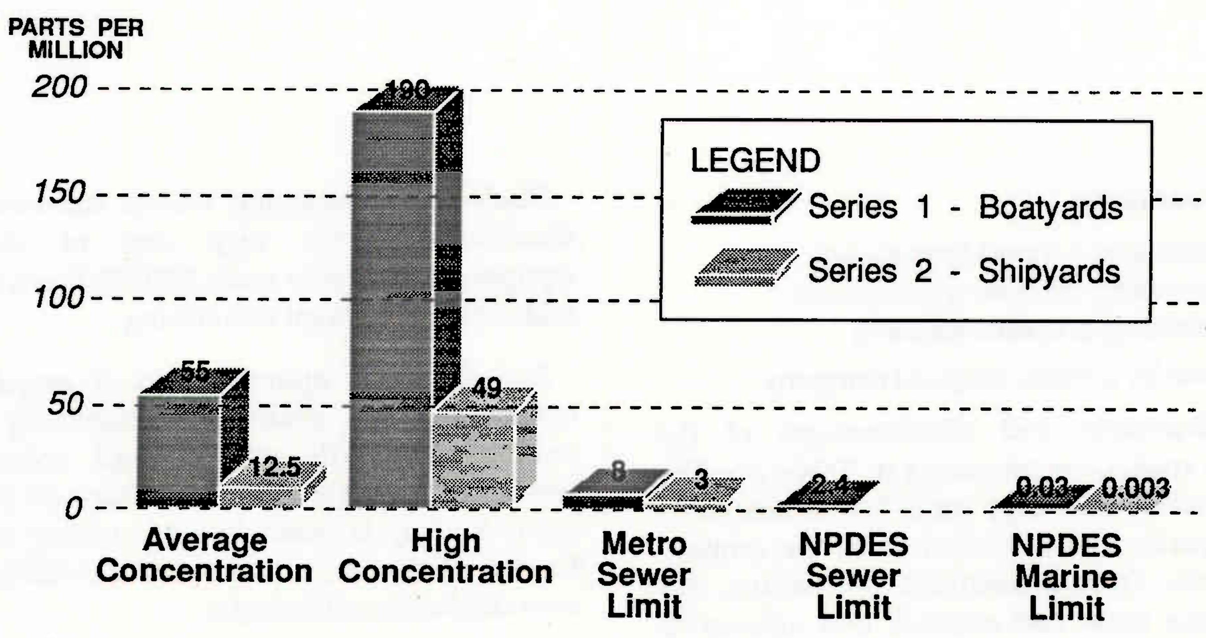
Discharge to receiving waters has two major disadvantages: the high cost of treatment equipment needed to reach NPDES limits and the added cost of effluent monitoring.

Zero-discharge options, such as recycling or evaporation, are probably economically viable only at boatyards where small volumes of wastewater are generated or where no sanitary sewer hookup is available. More testing needs to be done, however, to determine the feasibility of zero-discharge technologies.

Table 2-5: Shipyard Pressure-washing Wastewater Contaminants and Regulatory Limits

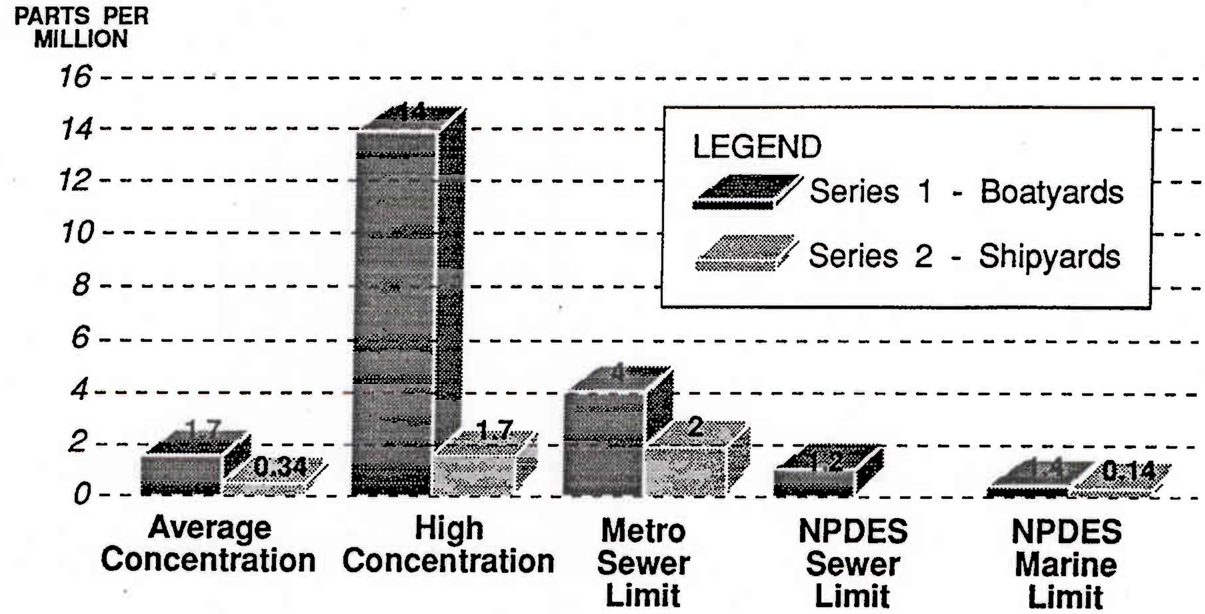
Analytical Parameter	Units	Untreated Sample (average) [1]	Untreated Sample (high)	Permit Limit Values: Sanitary Sewers (Metro)	Permit Limit Values: Receiving Waters [3]
pH	pH	7.3	6.1 - 8.7	5.5 - 12.0	6.0 - 8.0
Turbidity	ntu	176	840	[2]	[2]
Suspended solids	mg/l	261	693	[2]	45
Oil/grease	mg/l	20	31	100	15
Copper	mg/l	12.5	49	3.0	0.0029
Lead	mg/l	0.34	1.7	2.0	0.140
Zinc	mg/l	6.6	33	5.0	0.095
Tin	mg/l	0.34	1.6	[4]	[4]
Arsenic	mg/l	0.16	0.3	1.0	[2]

[1] Values based on results from 34 samples.
[2] No limit set or known for this parameter.
[3] Based on an individual NPDES permit recently issued by DOE to a shipyard.
[4] Tin regulated by restrictions of the application of Tributyltin paints.



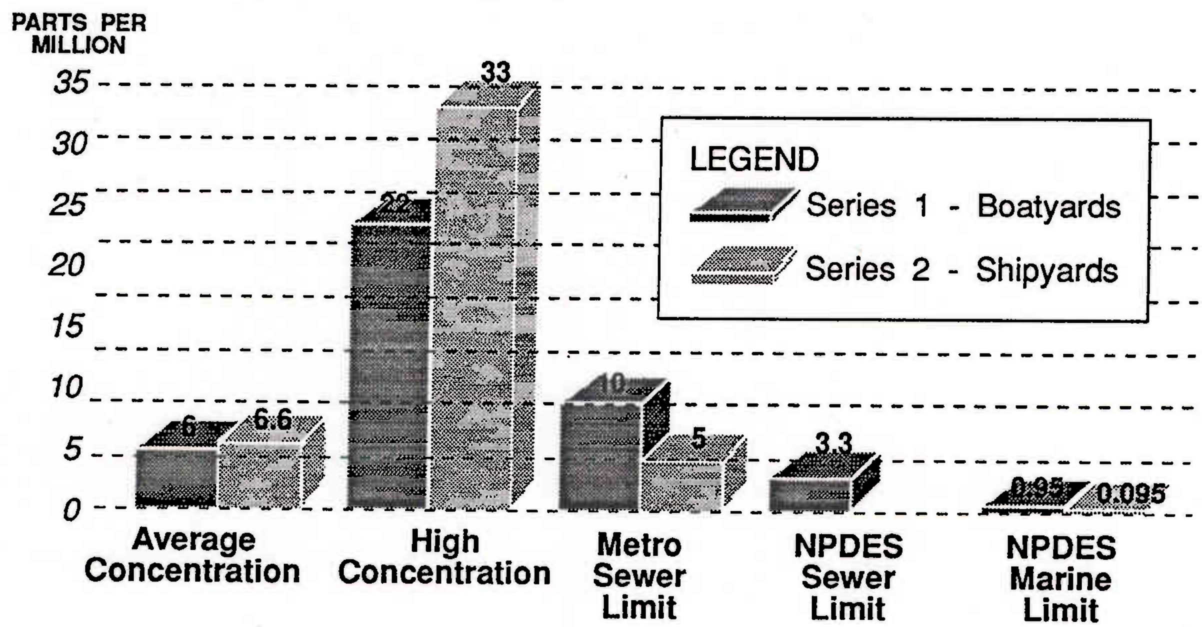
The boatyard NPDES marine limit value is based on a March 1992 draft of the Boatyard General NPDES Permit.
The shipyard NPDES marine limit is based on a NPDES permit recently issued to a shipyard.

Figure 2-2: Wastewater Concentrations and Regulatory Limits – Copper



The boatyard NPDES marine limit value is based on a March 1992 draft of the Boatyard General NPDES Permit.
The shipyard NPDES marine limit is based on a NPDES permit recently issued to a shipyard.

Figure 2-3: Wastewater Concentrations and Regulatory Limits – Lead



The boatyard NPDES marine limit value is based on a March 1992 draft of the Boatyard General NPDES Permit.
The shipyard NPDES marine limit is based on a NPDES permit recently issued to a shipyard.

Figure 2-4: Wastewater Concentrations and Regulatory Limits – Zinc

[redacted]

Table 2-6: Evaluation of Pressure-washing Wastewater Discharge Route

Discharge Route	Treatment Requirements	Advantages	Disadvantages
Receiving waters	High level – Requires treatment for dissolved metals. Reverse osmosis, ultrafiltration plus ion exchange, or distillation probably required.	None – Useful only if other options are unavailable.	High capital cost. High operational cost. Holding-tank capacity required. High monitoring costs.
Sanitary sewers	Moderate level – Requires removal of major portion of suspended particles. Settling and filtration, chemical flocculation and settling or filtration, dissolved-air flotation, or ultrafiltration required.	Moderate capital costs. Low holding-tank capacity. Moderate permit and monitoring costs.	Sanitary sewer permit required. Permit monitoring and reporting required.
Zero-discharge (recirculation)	High level – Requires removal of most particulates. Similar technology to sanitary sewer discharge, plus final polish filtration and bacterial control, required.	No permit requirements for treatment system discharge. Water conservation.	High maintenance requirements. Potential bacterial problems and pressure-washer degradation.
Zero-discharge (evaporation)	High or moderate level, depending on wastewater volume. Evaporation system required.	No permit requirements for treatment system discharge. Off-site waste disposal minimized.	High capital equipment costs. High operational costs.
Haul-away by waste disposal company	None.	Low capital costs. Low maintenance. Low permit requirements.	High disposal costs. On-site storage capacity required.

3. Technology Review And Project Participants

Review and Consideration of Appropriate Treatment Technologies

The Maritime Industrial Waste Project initially identified the objectives for treatment of wastewater from hull-washing as the reduction or removal of contaminants to concentrations that would allow the wastewater to be discharged to either sanitary sewers or receiving waters.

Wastewater characterization data was used to determined which wastewater components needed to be reduced or removed for effective wastewater treatment. As the project received more information about the concentrations of contaminants in wastewater and the concentration limits proposed in the new NPDES permits for receiving water discharge, it became obvious that treatment for sanitary sewer discharge was more feasible and cost-effective than treatment for receiving water discharge. This conclusion is discussed in more detail in Chapter 4.

The following technologies or systems were identified as potentially effective for treating wastewater for sewer discharge:

- Chemical flocculation
- Ultrafiltration
- Diffused-air filtration
- Microfiltration
- Sand filtration
- Precoat filtration
- Electrolytic removal
- Multimedia filtration
- Multiple technology systems, usually involving oil/water separation, settling and multimedia filtration
- Filter press.

The project identified the following criteria for general treatment systems:

- Removal of a high percentage of suspended solids.
- Ability to treat small particle-size solids, which have a tendency to foul or plug simple filters.
- Efficient mechanisms for holding and removing solids from the treatment system.

The project concluded that the following characteristics are also desirable for treatment systems to have:

- Labor efficiency and simple system maintenance.
- Technology appropriate to the level required for treatment.
- Flexible capacity to allow for the range of possible wastewater volumes that might be generated at a boatyard or a shipyard.

Since it was found that a majority of maritime businesses had little or no experience with wastewater treatment, the project recognized that viable technologies and systems would have to be uncomplicated, understandable, and suitable to an industry unaccustomed to wastewater treatment.

To satisfy this condition, the project identified two technological approaches. One approach is to use highly automated turn-key systems that treat wastewater with minimal labor and operator control. This type of system requires minimal understanding of the system's physical or chemical operation. The other approach is to use the simplest, yet most effective, technology that a boatyard or shipyard can develop or assemble on-site. This type of system may incorporate some manufactured components but generally uses less automated controls. To operate these systems, operators must develop hands-on treatment skills.

Each of the two approaches had its disadvantages. The turn-key system has higher initial costs. The other system has higher costs in labor and training. Because of the range in abilities of shipyards and boatyards to pay for automated systems or commit resources to labor and training, the project decided to include both types of systems in this study.

Treatment System Suppliers

To obtain commercially available treatment equipment for pilot-testing, the project sent out a letter of invitation (Appendix C) to 151 companies identified as likely to have equipment that would meet the general criteria for effective treatment. Local and national companies were represented about equally. To invite the largest response possible, the letter described the treatment objectives generally. The 151 equipment suppliers were selected from a number of sources, including *Chemical Engineering Equipment Buyer's Guide, Pollution Equipment News Buyer's Guide, Pollution Engineering* and local yellow pages.

To involve as many local equipment suppliers as possible, the project adopted a broad view of potential treatment systems, allowing equipment suppliers to determine their equipment's applicability as they learned more about the treatment objectives.

Metro received 30 responses from the 151 letters of invitation. Of the 30 responses, 13 suppliers indicated an interest in pilot-testing their equipment.

Metro sent a follow-up letter to those responding to the first letter to provide more details of the project and some wastewater characterization information (Appendix C). Metro also invited the suppliers to attend two meetings in March 1991 to establish guidelines for the pilot-testing program and determine their commitment.

The project also contacted two boatyards and one shipyard already implementing or testing yard-developed treatment systems. All three agreed to participate in the pilot-testing program.

Table 3-1 lists the equipment suppliers that participated in the program.

Maritime Business Participants

The maritime business survey identified shipyards and boatyards that were interested in participating in the project either as a pilot-test site or a wastewater characterization site. The project contacted these businesses and arranged site visits to discuss the pilot-testing program. Table 3-2 lists the maritime businesses that participated in the program.

Procedures and Conditions for Pilot-testing

Metro developed a document for both equipment suppliers and maritime businesses outlining procedures and conditions for the pilot-testing program. This document covered program objectives; responsibilities for equipment, labor and finances; use of company names and logos; and dissemination of project data. A copy of the document is presented in Appendix D.

[redacted]

Table 3-1: Maritime Industrial Waste Project – Commercial Pilot-equipment Suppliers

Company	Treatment Equipment	Address
Northwest Filter Co.	Mixed-media filtration	345 Upland Dr. Tukwila, WA 98188
IEECO	Hotsy oil-water separator	7622 146th St., Ct. E. Puyallup, WA 98373
American Equipment Co. of Washington	RGF filtration system	4401 Pacific Highway E. Fife, WA 98424
Columbia Pacific & Associates	Landa filtration system	7451 S.W. Coho Court, Suite 103 Tualatin, OR 97062
Columbia Pacific & Associates	Koch ultrafiltration	7451 S.W. Coho Court, Suite 103 Tualatin, OR 97062
Blace Filtronics Inc.	Blace precoat filtration	10914 N.E. 39th St., Suite B-2 Vancouver, WA 98662
Delta Pollution Control Inc.	Delta flocculation and filter press	30540 S.E. 84th St. Preston, WA 98050
Environmental Associates Inc.	Beckart induced-air flotation	460 S.W. Madison, Suite 1 Corvallis, OR 97333
Courtney & Nye	Krofta dissolved-air flotation	P.O. Box 787 Milton, WA 98354